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NASA TECH BRIEF

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Final Report on a Study of Low-Density Nozzle Flows, with Application to Microthrust Rockets

The problem:

The rocket engines that are used for satellite attitude control are often required to produce a thrust less than one pound force (4.5 Newtons), extending in some instances to values as low as 1×10^{-6} lbf (4.5×10^{-6} Newtons). Such low values of thrust dictate the use of low reservoir pressures and small nozzle scale; the result is that the flow takes place at very low Reynolds numbers, where viscous effects are felt all across the nozzle cross-section. Thus, it is not possible to calculate the performance of these devices by the usual inviscid, one-dimensional flow approximation, with a small correction due to a thin boundary layer.

The solution:

A study was made which led to a method of predicting nozzle performance in the major portion of the Reynolds number range appropriate to microthrust rockets. The method is a numerical one, and a relatively simple computer program has been developed for applying it.

How it's done:

The analysis is based on the slender-channel equations, with slip boundary conditions at the walls. The solution is started upstream of the throat, using asymptotic results for slow viscous flow in a converging cone. An implicit finite-difference scheme is then used to calculate the pressure, and profiles of velocity and enthalpy at successive stations along the channel.

The cases presented show the effects of the nozzle geometry, the Reynolds number, and the thermal condition of the nozzle wall. Results found with the program show good agreement with experimental data.

Inputs to the program include reservoir conditions, the nozzle geometry, the gas properties (such as the specific-heat ratios), and (if heat transfer is allowed) the distribution of wall temperature. The program determines the mass flow, and then prints the pressure, thrust coefficient, and profiles of velocity, density, and static enthalpy at selected stations along the nozzle.

Notes:

1. The user is to either remove or supply his own subroutines called CLEAR and DVDCHK. CLEAR inserts a zero for all the variables in the common block, while DVDCHK specifies the procedure to be used if overflow, underflow, fixed, or floating-point divide errors are encountered.
2. This program has been used as an aid in the design of low-density wind tunnels.
3. This program is written in FORTRAN G or H for the IBM-360/65 computer.
4. Inquiries concerning this program should be directed to:

   COSMIC
   112 Barrow Hall
   University of Georgia
   Athens, Georgia 30601
   Reference: HQN-10761

Source: Cornell Aeronautical Laboratory, Inc.
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